THE PREVENTION OF MALARIA IN MILITARY FORCES IN THE SOUTH PACIFIC

I. Introduction.

Experience has shown that organized and properly directed preventive measures against malaria in military forces in the South Pacific Area, will check the disease to a degree which will permit the successful accomplishment of military operations. Failure to take steps, however, will result in an enormous degree of sickness and loss of man days, as might well be expected in the conduct of war on some of the most malarious islands in the world.

The control of malaria is a joint responsibility. It requires the cooperation of both line and medical officers, and of the men serving under them, and that their efforts be directed along productive channels by persons with special knowledge of the disease. The control of malaria further requires that all concerned have general knowledge of the manifestations of the disease, and particularly of the preventive measures which are applicable under special military conditions.

In the notes to follow, the general nature of the program being undertaken in the South Pacific Area is outlined; certain principles, which past experience indicates as best in the handling of specific problems are stated; and most important, various responsibilities are defined. In the actual application of measures enumerated herein, it is obvious that many modifications will be necessary and that considerable ingenuity will be required in order that the desired end result may be obtained.

II. GEOGRAPHICAL DISTRIBUTION OF MALARIA IN THE SOUTH PACIFIC AND CERTAIN ADJACENT AREAS.

A. Malarious Islands. Malaria is present in hyperendemic form on a large number of islands involved in the Pacific campaign. Certain other islands in near proximity, remarkably enough, are entirely free of malaria. From a practical standpoint, all islands of the New Hebrides and those North and West thereof may be considered malarious (North of 20 degrees S. latitude, to the equator, and west of 170 degrees E. longitude.)

B. Nonmalarious Islands. New Zealand and New Caledonia are malaria-free, as are also islands of the Loyalties, Fiji, Samoa, Cook, Tonga, Society, Gilbert, Ellice, Hawaii,

Tahiti, and Nauru and Ocean Islands. The absence of malaria in these islands is due essentially to the fact that no anopheline mosquitoes are present. Only mosquitoes of this genus are capable of transmitting the disease.

Although reports have indicated the presence of anophelines in New Caledonia as late of 1939, to date, no proven cases of locally acquired malaria have been encountered. Very recent surveys and those now in progress have not disclosed the presence of any anopheline species.

III. TOPOGRAPHICAL AND SEASONAL ASPECTS.

A. Topography. It is of highest importance in the selection of campsites on malarious islands that the remarkable difference in the malariousness of various parts of each island be recognized. Of two closely adjacent sites, equally satisfactory from a tactical standpoint, one may be highly dangerous and the other free of malaria. To prevent errors in selecting campsites, a directive has been issued, (reference A, par. 6), requiring that Malaria Control Units assigned to each base be consulted.

B. Season. In general, the prevalence of malaria in the South Pacific fluctuates markedly according to season. During the rainy season which usually extends from November to May, mosquito densities are apt to become high, and during such periods the malaria incidence reaches its peak. One may expect a lag of 1 month following the onset of the rainy season before the incidence of malaria increases to any great extent. Similarly, a like period occurrs after the end of the rainy season before the incidence declines appreciably.

During the dry season (approximately May to November) malaria rates may be expected to drop to relatively low levels.

IV. NATURE OF THE DISEASE IN THE SOUTH PACIFIC AND ITS TRANSMISSION.

A. The mosquito vector. Many species of mosqnitoes have been identified in the islands of the South Pacific, but only one, **Anopheles punctulatus moluccensis,** Swell. and Swell., transmits malaria from man to man. All other mosquitoes are "pest" mosquitoes, and are harmless so far as their ability to transmit malaria is concerned. **A. punctulatus** breeding in the dry season is largely confined to quiet eddies along the grassy margins of streams. In the wet season it breeds additionally, in numerous newly formed collections of water over widespread areas. During the rainy season when breeding becomes intense, this species of mosquito becomes most indiscriminate in its choice of breeding places. Its larvae then may be found not

only in clear pools of water, but in stagnant or muddy pools, occasionally in brackish water, and very rarely in small containers such as tin cans. A fortunate exception to this rule is that cocoanut half-shells, although a prolific source of pest mosquitoes, do not create an anopheline problem.

B. Reservoir of infection. Natives are the principal source from which the anophelines become infected and are able to transmit the disease to troops. Studies on groups of apparently healthy natives have shown that as high as 80 percent are carriers of the disease. Whenever natives have been imported for labor purposes and permitted to live near troops, or where camps have been established in near proximity to native villages, malaria has appeared, sometimes in epidemic proportions. After malaria has "seeded" troops, they in turn also become sources of infection.

C. Relative prevalence of the three species of malaria. Three of the known species of the malaria parasite have been found in the South Pacific: **Plasmodium vivax,** causing benign tertian malaria; **Plasmodium falciparum,** causing malignant malaria; and **Plasmodium malariae,** causing quartan malaria. The relative prevalence of the three types of malaria varies considerably. In very general terms it may be said that about one-half of the **primary** cases will be benign tertian, one-half malignant tertian, and 1 or 2 percent will be of the quartan type. Although the strain of **P. falciparum** encountered in this part of the world has in the past been declared exceedingly virulent, in military forces it has caused but few deaths, and pernicious manifestations have been surprisingly infrequent. The strain causing benign tertian malaria, while rarely if ever exhibiting pernicious symptoms has created a serious problem because of its marked tendency to repeated relapse, despite adequate therapy. Malignant tertian malaria has not shown this tendency. The infrequent cases of quartan malaria have shown poor response to specific therapy and have recurred frequently.

V. TREATMENT OF CLINICAL MALARIA.[1]

A. Choice of drug. Three drugs have been widely used in the treatment of clinical malaria, namely, atabrine, quinine and plasmochin.

1. Atabrine. Evidence indicates that **atabrine is as effective as quinine,** and in many respects to be preferred. This fact plus an impending critical shortage of quinine dictates the routine employment of atabrine. A former disadvantage of atabrine, a clinical response slower than that obtained with quinine, has been overcome by the employment of higher initial dosage. Another former objection, the so-called toxicity of atabrine, has not been substantiated by wide experi-

[1] Sections V & VI revised by the Division of Preventive Medicine, Bumed, Navy Department.

ence. **Toxicity of atabrine now appears to be less than that of quinine.**

2. **Quinine.** A few indications which demand the use of quinine derivatives remain: atabrine may not be available; or rarely an individual will show intolerance to the drug. It is also generally agreed that quinine (intravenous) is preferable in patients critically ill with malaria, as it appears to be a less dangerous drug than intravenous atabrine and more rapidly acting than intramuscular atabrine.

3. **Plasmochin.** This drug has been combined with quinine in the treatment of malaria, or has been used to follow a course of atabrine. **It is not efficacious as the sole drug for therapy.** The toxic and therapeutically effective doses tend to coincide. Formerly, its use was advised in order to reduce the relapse rate in **P. vivax** infections. Recent evidence discloses no appreciable effect in this regard. It has some action in the destruction of gametocytes, and consequently may be useful in reducing the spread of malaria. In certain cases, where gametocytes persist in the blood stream following usual treatment with atabrine or quinine, the addition of a course of plasmochin may be useful in destroying these sexual forms.

B. Laboratory diagnosis. Where competent film examination of the blood is possible, **it is inexcusable to start specific chemo-therapy without a positive laboratory diagnosis**, except in the urgently ill case where no delay can be safely permitted. The habitual employment of atabrine or quinine in all fevers in a malarious area, before demonstration of the parasite, is a dangerous practice which on occasion will result in the death of a patient. **A negative thick film** casts doubt upon a diagnosis of malaria, and should lead to close observation to determine if the fever is of other than malarial etiology.

1. **Under combat conditions, or lacking laboratory facilities,** it may become necessary to treat patients without blood confirmation of the diagnosis. Keen observation then becomes essential so as not to miss the occasional case of meningitis, pneumonia, or other febrile disease which may simulate and mistakenly be assumed to be malaria.

2. **Importance of species diagnosis.** Where possible, in addition to parasite diagnosis, **species** diagnosis should be attempted. A diagnosis of **P. falciparum** infection will dictate close observation of the patient for the onset of pernicious symptoms; furthermore, relapse may be predicted as unlikely. In contrast, a patient with a **P. vivax** infection is not likely to develop critical symptoms, but is apt to have continued relapses over a prolonged period.

3. **Verification of technical proficiency.** It is important to note that the accurate diagnosis of malaria by either thin or thick film technique requires prolonged experience, particularly in the case of the thick film procedure. False positives in which blood platelets are mistaken for plasmodia are the commonest errors. Technicians should be required to check

continuously with other competent laboratories to determine the reliability of their own work.

C. Drug intolerance and toxic manifestations in the use of atabrine, quinine, and plasmochin. Each of these drugs may give rise to untoward symptoms in occasional individuals. Severe reactions are most common with plasmochin.

1. Atabrine. Toxic symptoms of any type are unusual in the use of atabrine in the treatment of clinical malaria. Symptoms of nausea, vomiting, diarrhea, abdominal cramps, and headache, which have been reported in normal individuals taking atabrine for the first time for suppressive treatment, are uncommon in the therapeutic use of the drug, and are more apt to be due to malaria than to the drug. Occasionally, mild excitement has been ascribed to the effect of atabrine; rarely, there have been reported acute maniacal toxic psychoses which subsided on withdrawal of the drug and recurred on readministration. Occasional urticarial and scarlatiniform rashes, and rare exfoliative skin reactions, have been reported. The etiological relationship of these toxic manifestations has not always been conclusively demonstrated. While it is well to appreciate the toxic possibilities, experience with the drug will in the vast majority of cases tend to emphasize its relative nontoxicity. Exceeding recommended dosage, however, may lead to toxic effects. The drug is a dye and a yellow skin deposit which occurs in certain cases should not be interpreted as a toxic sign.

2. Quinine. As with atabrine, the administration of quinine leads in the great majority of patients to few untoward effects. **Effective therapeutic dosage,** however, is usually accompanied, to a more or less degree in almost every patient, by one or more of the following symptoms: tinnitus, dizziness, temporary deafness, tremors and palpitation. These milder symptoms indicate adequate blood levels for favorable therapeutic action, but are quite objectionable to many patients.

More rarely severe untoward reactions occur and are definitely ascribable to quinine. These are generally allergic in nature. Suspicion also points to quinine as an important precipitating factor in blackwater fever. Prolonged use of quinine has been reported as the cause of permanent impairment of hearing.

3. Plasmochin. Effective dosage with this drug frequently leads to toxic manifestations. Symptoms include abdominal pain (which may be severe enough to require morphine), nausea, vomiting, headache, dizziness, and drowsiness. Acute yellow atrophy of the liver, jaundice, and hemoglobinuria are rarer, exceedingly dangerous effects of the drug.

D. Recommended treatment for clinical malaria.

1. Uncomplicated malaria (patient able to retain oral medication). Atabrine dihydrochloride 0.2 gram (3 grains) every 6 hours, night and day, for five doses; follow by 0.1 gram (1½ grains) three times daily, after meals for 6 days (total of 2.8 grams in 7 days).

2. Malaria complicated by vomiting (unable to retain oral medication). Atabrine dihydrochloride 0.2 gram (3 grains) in 5 cc. sterile distilled water injected intramuscularly with the usual precautions into each buttock (total 0.4 gram or 6 grains). If necessary, one or two additional doses of 0.2 gram (3 grains) may be given intramuscularly at intervals of 6 to 8 hours. As soon as the patient can take and retain oral medication, atabrine should be given by mouth in such dosage as to give a total by both routes together of 1.3 grams in 48 hours, followed by 0.1 gram three times a day after meals for 5 days (total 2.8 grams in 7 days). Intramuscular atabrine might well be used where serious illness is anticipated or where complicating disease exists. **A maximum blood concentration** of the drug is obtained about 1 hour after the intramuscular injection.

3. Malaria complicated by coma or impending coma; or by high parasite blood film density (P. falciparum infections) even when patient does not appear critically ill (par. G–3–b). Quinine dihydrochloride 0.6 gram (10 grains) in 300–400 cc. of sterile physiological saline injected very slowly intravenously. This treatment may be repeated in 6 or 8 hours if required, but it will be better to anticipate the need by giving intramuscular atabrine immediately following the intravenous quinine. The intravenous quinine is eliminated in about 3 hours. When the patient can take and retain oral medication, a complete course of atabrine should be given as for uncomplicated malaria.

E. Supportive measures.

1. Keep patient in bed and maintain fluid intake at 3 to 4 liters daily, if necessary by intravenous administration. Sweetened tea and fruit juices are usually well accepted by the patient. If sweating leads to considerable fluid loss, maintain chloride level with salt administration. Hot water bags and blankets should be used during the chill; cold sponges and packs when fever is high. Antipyretics are not recommended since they may mask symptoms and increase fluid and salt loss.

2. When nausea or vomiting is present, stop intake of solid food, particularly when a paroxysm of fever is expected. Give sips of alkaline water. If vomiting becomes frequent inject dextrose intravenously using a 5 percent solution in normal saline; or more slowly, by the continuous drip method. One milligram of thiamine hydrochloride for each 25 grams of dextrose should supplement dextrose administration.

3. During convalescence, a liberal vitamin and iron intake is usually advisable.

F. Alternative treatment schedules. The drug routine recommended in paragraph D will be effective in the vast majority of cases encountered. In the past, in the hope of lessening the number of relapses, almost every conceivable variation

of these methods has been attempted in treating cases. These variations have embraced increased dosage, and prolongation of administration of various drugs, singly or in combination, all without appreciable increase in efficacy. Deviation from the recommended schedules therefore should be only for the purpose of meeting specific individual indications. In the case of quinine, its routine use is specifically prohibited by directive.

1. Quinine by mouth. The sulphate, or hydrochloride (the latter is more readily absorbed) 1 gram (15 grains) by mouth after meals three times daily for 2 days. Continue with 0.6 gram (10 grains) t. i. d. for 5 days.

2. Quinine intramuscularly. Quinine dihydrochloride, 1 gram (15 grains) in 10 cc. of sterile physiological saline. **Sterile technique should be scrupulous,** and injection made into the buttock taking care to miss the large nerves and vessels. Massage area of injection for 2 or 3 minutes. Intramuscular quinine has gained a reputation as dangerous owing to abscess formation. However, its routine use without ill effects, also has been reported. As soon as possible oral medication should be resumed.

3. Plasmochin (see indications in paragraph A–3). The drug may be given concurrently with the administration of quinine, or immediately following (but never with) atabrine treatment. Give 0.01 gram (⅙ grain) by mouth t. i. d. after meals for 4 days. **The drug should be administered under careful medical supervision. It should not be given to debilitated patients. Each dose should be accompanied by at least 1 gram of sodium bicarbonate.** Toxic symptoms of various degrees of severity are apt to occur in the dosage above, in which case the drug should be stopped promptly.

G. Practical points in the management of malaria.

1. Pertaining to diagnosis.

(a) Suspect malaria regardless of admission diagnosis. It is a cardinal point that where the possibility of malaria exists, the diagnosis of malaria should be considered on every admission no matter how unrelated the symptoms and signs may at first appear to be. Malaria is apt to manifest itself in many guises. Fever is not always essential; indeed a patient critically ill with the disease may have a subnormal temperature.

(b) Importance of laboratory confirmation of clinical diagnosis. Repeated thick film studies by competent technicians should be undertaken in every undetermined malaria diagnosis until parasites are demonstrated. Most authorities agree that over 90 percent of cases of malaria will, with competent examination, show malaria parasites on the first or second film examination provided the patient has not recently been under treatment. The symptoms and signs of a patient showing repeatedly thick negative films, are almost surely not due to malaria.

(c) Significance of clinical response to specific therapy. Where a clinical diagnosis of malaria, unconfirmed by laboratory examination, has been made, favorable response to specific malarial drugs nevertheless does not prove that the fever was of malarial origin. On the other hand, failure of response (when it can be assured that the patient has taken and has absorbed the drug) is almost positive indication that a case is not of malarial etiology.

2. On the prior use of suppressive treatment.

(a) High parasitemia indices in hospital admission irrespective of admission diagnosis. In certain highly endemic areas as high as 95 percent of groups of men exposed develop latent malaria on atabrine suppression regimes. Thus when atabrine is stopped during hospitalization for any cause, a parasitemia is apt to develop and confuse the true condition. The finding of parasites in the blood of such patients may have nothing to do with the complaints for which the patient was admitted.

(b) Lack of parasite resistence in prolonged atabrine usage. Experience with atabrine indicates that the parasite does not develop drug resistance following its continued employment in suppressive treatment. Patients "breaking through" atabrine suppression even when the suppression has been for prolonged periods, promptly respond to the usual dosage employed in the treatment of clinical cases.

(c) Effect of suppressive treatment in detecting parasites in clinical break-throughs. The employment of suppressive treatment, prior to a clinical break-through, does not appear to reduce appreciably the chance of demonstrating plasmodia in thick films.

(d) Treatment in asymptomatic parasite-positive cases. Patients who have been under suppressive treatment may show parasites and yet be clinically free of the disease on admission. In such cases the patients should receive the same course of chemo-therapy as the acute case.

(e) Factors precipitating clinical malaria from latency. Patients who have been on suppressive treatment and who are ill from other causes, are especially apt to come down with clinical symptoms of malaria when latency has existed. Surgical operations, trauma, and shock particularly are apt to precipitate clinical attacks. Patients apt to have latent malaria should be given full therapeutic treatment promptly, if malaria supervening on another condition might endanger chances for recovery.

3. In P. falciparum infections.

(a) Rapid development of critical symptoms. The very sudden onset of pernicious symptoms in malignant tertian malaria is common enough to indicate very close observation of patients with this type of malaria. The presenting symptoms in **P. falciparum** infections may be very urgent in nature. Patients, who a few hours previous to entry appeared

well, may be admitted in coma or with convulsions; with hyperpyrexia, or with subnormal temperature. Intravenous therapy should be instituted at once. In such cases the critical condition of the patient may not warrant waiting for laboratory confirmation of the diagnosis.

(b) High parasite densities in P. falciparum infections. When the proportion of red cells infected with plasmodia exceeds a ratio of 1–20 red cells, a critical condition of the patient is impending if not already present, and energetic specific therapy is indicated. Usually intravenous medication should be given at once.

(c) In cerebral malaria. Lumbar puncture is definitely indicated as a therapeutic adjunct in cerebral malaria. Drain off the cerebral spinal fluid until the pressure is completely relieved or even subnormal.

4. Pertaining to treatment in special circumstances.

(a) Species differences; relapse vs. primary case. The recommended treatment described above is in general satisfactory regardless of the species of plasmodia causing malaria, or whether the case is a primary infection or a relapse.

(b) Parasitemia without clinical evidence. Cases should receive same treatment as in uncomplicated clinical malaria.

(c) Interval treatment in the absence of parasitemia or clinical manifestations. There is no evidence that repeated courses of therapy given during asymptomatic intervals is of benefit.

(d) Failure of clinical response in laboratory confirmed cases of malaria. Patients who show either clinical or parasitic relapse, during or shortly after a full course of therapy, should be carefully studied to see that they are actually taking the prescribed dosage. When failure to take the drug can be ruled out, poor absorption is likely. In this case intramuscular atabrine administration may be resorted to, or a shift to quinine may be tried.

H. Postmortem examination. When a death presumably due to malaria occurs, certain special procedures for confirming the cause of death are indicated.

1. The characteristic gross appearance of the liver, spleen and brain should be observed.

2. Smear preparations should be made of the bone marrow, splenic pulp and brain tissue. These preparations must not be too thick and tissue must be teased out into a thin layer.

3. All smear preparations should be fixed with methyl alcohol and stained with Giemsa. Tissue for sectioning should be fixed with Zenker's solution for 8–10 hours, washed in several changes of water or in running water for about 6 hours, then preserved in 70-percent ethyl alcohol to which tincture of iodine has been added in sufficient amount to tint the solution a straw color.

VI. SUPPRESSIVE TREATMENT. (Chemoprophylaxis.)

A. General considerations. Although there is no known drug which will prevent malaria infection, two drugs, atabrine and quinine, when properly employed, will **delay the onset of symptoms of the disease.** These two drugs are therefore useful to keep men on their feet during urgent military operations where illness from any cause must be kept to an absolute minimum.

Eventually, when the drugs are discontinued, those individuals who have become infected during periods of suppressive treatment, will become acutely ill with malaria. Recent evidence, however, suggests that when suppressive treatment is taken as recommended, a certain proportion of **P. falciparum** infections will never become clinically active. In such cases it appears that continuous suppression may lead to actual cure. There is also a likelihood that atabrine suppression may lessen the severity of symptoms when clinical activity supervenes during its routine use. Parasite resistance to atabrine fortunately does not appear even after prolonged suppressive usage, for clinical cases which occur in spite of suppressive treatment respond promptly to further treatment with atabrine in the usual clinical doses.

B. Objections. Early experience appeared to indicate that a very serious drawback to suppressive treatment was that it failed to hold acute symptoms of malaria in check under conditions of combat. However, it has been definitely proved that in those units where good atabrine discipline obtained, clinical break-through was relatively rare, even under most severe combat conditions. It should, therefore, be determined that atabrine is being taken as prescribed, before its value as a suppressive is questioned.

Since experience has shown that, when properly used, atabrine is highly effective, a particularly hazardous aspect of its employment is that it may dangerously conceal the amount of malaria which may be gradually seeding a unit. The apparent well-being of the organization concerned, in regard to malaria, leads to carelessness in the enforcement of individual protective measures, and commanding officers of units are apt to regard these, and other truly important preventive measures, such as mosquito control, as not necessary. A further possible objection to the use of suppressive therapy is that while evidence of toxicity has been remarkably absent when employed in recommended doses, one cannot be certain as to the possibility of long term, chronic toxicity of atabrine when the drug has been used over greatly prolonged periods. **As excellent as atabrine has proved itself in those military situations which deny the possibility of control by truly preventive measures, its continued use to the neglect of, and as a substitute for such measures, is inexcusable.**

C. Drug of choice. Where suppressive treatment is essential, atabrine is the drug of choice. Not only is quinine prohibited for routine use but experience in this area has shown that atabrine is better tolerated and preferred by troops. In rare instances when individuals are unable to take atabrine, quinine may be employed in 10 grain daily doses as a substitute, provided that a medical officer has specified such to be necessary.

D. Atabrine intolerance. In the early phases of initiating a program of suppressive treatment, it is not uncommon for from 5 to 10 percent of individuals to show symptoms of intolerance. Under conditions of improper administration, a very much higher percentage of untoward reactions has been experienced in occasional groups. Usually in such instances it is found that the drug was administered on an empty stomach. Often the fairly large initial dose of two tablets (0.2 gram) will cause trouble in individuals; occasionally one tablet may do so. Reactions are unusual when one-half tablet (0.05 gram) is employed. Whenever diarrhea and enteritis have been prevalent in groups prior to the first administration of the drug, the amount of intolerance has been excessive.

The most common untoward symptoms experienced are nausea and vomiting, usually coming on several hours after taking the atabrine. Abdominal cramps and diarrhea are not unusual. Later on, during the continued administration of the drug, a yellowish discoloration of the skin may appear. This is not a sign of toxicity, but is due to the dye content of the drug, and will disappear after the drug is discontinued. The drug is a cumulative one and continues to be excreted for some time after its use is stopped.

After the phase of initial intolerance is over, it will be found that less than 1 percent of any group will be unable to continue with the drug. Medical officers, by correcting the mistakes pointed out above, and by reducing the dose for temporary periods in individuals who experience difficulties will find but rare cases of persistent intolerance.

E. Dosage. Almost any dosage of atabrine within the prescribed safe limits, will be followed by instances of "clinical break-throughs." The factors that cause these break-throughs are only partially known but by far the most important is failure to take the prescribed doses of the drug. It is probable that whatever the conditions, any group of men taking 0.7 grams of atabrine per week **with absolute regularity** will maintain a highly efficient suppressive blood level. In practice, however, even under the best of conditions there is a failure to take the prescribed doses regularly. Under various conditions, especially combat, this failure becomes very much more marked. For this reason the paragraphs below recommend augmented dosage of atabrine to foresee and compensate for those conditions in which there is increasing likelihood of a failure to take the drug.

Standard dosage. Give one tablet of atabrine (0.1 gram) daily after a meal, a total of 0.7 gram in a week. This routine leads to relatively few cases of initial intolerance and virtually no cases of continued intolerance.

Under conditions of great military urgency, such as actual combat, atabrine may be increased for short periods to two tablets daily. It is important that these larger doses be administered only after troops have become adjusted on the smaller dosage regimen, and that they be reduced promptly when the critical period is over.

Occasionally, in urgent military situations, when a considerable number of "clinical break-throughs" are occurring despite the administration of 0.7 gram of atabrine a week, the malaria rate may be reduced by giving three tablets (0.1 gram each) daily after meals, under supervision, for a period of 3 to 7 days. Revert then to the regular 0.7 gram a week schedule.

Obviously the above methods of increased dosage, i. e., of "loading," must be carried on only to meet critical conditions, and then with as much conservatism as possible in order to minimize the possibility of toxic effects. Experience to date indicates that the margin of safety is fairly great; indeed, the amount of harm occasioned by a high malaria incidence appears to be by far the greater hazard.

F. Supervision. If conditions are urgent enough to necessitate atabrine suppressive treatment, it is equally urgent that a proper system of supervision of the taking of the drug be required as follows: That the drug be administered by roster to both officers and men; that a competent noncommissioned officer witness the actual swallowing of the drug by each individual; and, that by checking the roster regularly, all individuals who have not taken the drug be required to report and take the sufficient dosage to equal that missed.

G. When to start suppressive treatment. In the past medical officers have on occasion instituted suppressive treatment in their organization prior to arrival at a malarious base, and upon landing, found that none of the other troops were employing chemo-suppression. On certain bases, control measures have succeeded to the extent that atabrine suppression is no longer required. Thus, before initiating a program of suppression it is best to request instructions by despatch from the area malaria control officer. If specific instructions cannot be obtained, medical officers should advise their commanding officers to withhold atabrine until after arrival and consultation with the permanently based malaria control unit at the malarious base concerned. If atabrine is found to be indicated at that time, suppressive treatment may be started after arrival without any fear that the situation might get out of hand.

Landing in a malarious area **under active combat conditions**, however, requires that the routine of administration be well established before arrival. One or two weeks should

be sufficient. If the malaria situation appears to be potentially very dangerous, "loading" (as described above) may be instituted during the preliminary period prior to landing.

In rare instances, a medical officer will not be able to estimate satisfactorily the necessity of employing suppressive treatment, or he may not be convinced of its desirability under the peculiar circumstances in which his unit will function. In such a case the conservative approach is to place the majority of the unit on suppression, but to omit a sample of sufficient size as a control in order to determine by the incidence of malaria in that group whether atabrine should be continued on all, or whether it may be safely stopped.

In heavily seeded units which are to reenter combat after a period of relative inactivity it is usually advisable to increase the group mean atabrine blood levels prior to the onset of combat activities by administering "loading" doses as described above.

H. Period of administration. Attabrine in total dosage of 0.6 gram a week has been administered continuously to troops for periods of many months with only an exceptionally rare case of serious toxicity having been reported.

I. When to discontinue suppressive treatment. Previously it has been recommended that upon withdrawal to nonmalarious, or relatively nonmalarious areas, that suppressive treatment be stopped. In heavily malaria-seeded units, the results even when the troops were staggered off treatment, have been most unsatisfactory. Hospital facilities have been flooded, and repeated relapses have been so numerous that major portions of units have been unable to rehabilitate or to undertake essential training maneuvers for periods of many months.

The present tendency is to continue the employment of suppressive treatment **in heavily infected units** for the duration of their activities in the theater of war, whether upon a malarious or nonmalarious base.

In units evacuated to nonmalarious areas, in which it is probable that heavy seeding with malaria has not taken place, the drug may be discontinued as follows: Stop the drug in a representative sample of two or three hundred men for a period of 4 weeks, but continue it in all others. This will permit an estimate of the amount of malaria to be expected in the entire unit and indicate whether suppression must be continued or can be safely stopped.

In any case where it is deemed advisable to stop suppressive treatment, it is preferable that atabrine in suppressive dosage be continued 4 weeks beyond the period of last exposure to malaria. Present evidence indicates that the employment of atabrine beyond the period of exposure will result in a "suppressive cure" in a considerable proportion of suppressed, latent **P. falciparum** infections.

VII. ORGANIZATION FOR THE DIRECTION OF THE CONTROL OF MALARIA.

Malaria Control Units have been established on all malarious bases. Their personnel, derived from the Army, Navy and Allied Forces, consists of malariologists, entomologists, engineers, trained technicians and other specialists in problems of malaria control. The direction of these units and all matters pertaining to malaria control in all forces is under the cognizance of an officer-in-charge, Malaria Control, South Pacific area. This officer, in turn, is directly responsible to the Commander South Pacific area and South Pacific Force.

A. General duties. It is the duty of Malaria Control Units to formulate antimalaria programs applicable to all forces occupying each base. These units are responsible for the technical direction of such programs and are required to submit to Commanding Generals, or other senior authority of each base, reports and recommendations which will insure effective control of the disease. (See reference A.)

It is a further duty of these units to supervise and direct the efforts of control units required within each of the various organizations serving at each base. In addition, they supervise and direct the efforts of mosquito control carried on by troop mosquito squads, by naval construction battalions, and by army sanitary companies.

B. Nature and scope of program. A peacetime program for control is neither possible nor applicable to the problem of fighting forces. Only rarely can the objective be the complete eradication of the disease. The contemplated measures must be such that the disease is suppressed to the point where it can constitute no real threat to the success of military operations. To attempt complete eradication would require diversion of man power and equipment vital to other phases of the war effort.

Although limited in the above respect, there still remains a very comprehensive undertaking, the scope of which is outlined in subsequent sections. (See section IX, seq.)

C. Malaria Control Units of non-malarious bases. Additional Malaria Control Units have been established on certain nonmalarious islands. These units serve principally to contact organizations about to enter malarious regions and to assist them in formulating an effective program for the prevention of malaria. Their duties also concern measures for the proper handling of evacuees from malarious areas. They have the responsibility of seeing that all feasible measures are taken to prevent the introduction of anopheline mosquitoes into their islands.

VIII. COMMAND RESPONSIBILITIES IN THE CONTROL OF MALARIA.

A. The responsibility for the control of malaria within each organization. This rests with unit commanders. Directives (see reference G) require that a special plan be placed in operation. Briefly, this plan (see appendices I and II of Training Manual No. 2) requires:

1. The appointment of a medical officer with specific duties and responsibilities in regard to malaria control.

2. The creation of "mosquito control squads" for mosquito elimination within and adjacent to the area occupied by the organization concerned.

3. The appointment of special malaria control inspectors to maintain a continuous check on the efficiency of measures within the organization.

4. A training program in malaria control so that all personnel may have an intelligent understanding of the disease and especially of preventive measures which may be employed by the individual.

5. The coordination of malaria control within the organization with the over-all program of control which is under the direction of base malaria control units.

B. Special control units within organizations. Special units composed of personnel similar to those in base units are being assigned to Army and Marine Corps divisions. These units have the general duties and functions required by the organization described in paragraph A above. They remain with their own organizations at all times.

IX. PREVENTIVE MEASURES APPLICABLE TO MALARIOUS BASES UNDER NONCOMBATANT CONDITIONS.

In the following paragraphs the nature of preventive measures applicable to noncombatant bases will be outlined. These measures may be classified at follows:

A. Measures for the protection of individuals from mosquito bites.

B. Elimination of anopheline breeding places.

C. The control of carriers of malaria.

D. Reduction of clinical cases by chemotherapy.

A. Measures for the protection of individuals against mosquito bites.

1. Proper selection of camps. Reference has already been made to the importance of the selection of suitable camping sites, and to the requirement that malaria control units

be consulted in each instance in which new sites are being considered.

From the malaria standpoint, the following general principles will govern: The terrain should be one that is unsuitable for the breeding of mosquitoes or one which can be easily rendered unsuitable. An entomologist is best suited to give an estimate of the malariousness of a given site. Besides actual breeding places, he takes into consideration the flight range of mosquitoes, the direction of prevailing winds, the proximity of natives, and breeding potentialties in both dry and wet seasons.

Because of the nature of the breeding habits of anophelines in this part of the world, it is frequently hazardous to locate camps on slow flowing rivers or streams. It is often preferable to pipe or otherwise transport water to more favorable areas away from rivers. This plan generally pays manyfold by preventing a large loss of man-hours from sickness due to malaria.

Steps should be taken to relocate camps in which the malaria rates are unduly high and where further control measures are difficult or impossible to accomplish.

Where the military situation permits, the consolidation of troops should be effected to lighten the burden of malaria control.

2. Screened protection. One of the most fundamental and effective measures for controlling malaria is the placing of individuals behind insectproof screens. As the project is one of considerable magnitude and will require time for general accomplishment, screening materials should be issued according to priorities. First, priority should be given mess halls and recreation quarters, as such screened buildings will protect the largest number of men during the hours of dusk and night which are the important biting periods. Obviously the most exposed organizations should be afforded the protection first.

(a) Methods. While screened prefabricated housing is preferable, other more simple methods such as the screening of pyramidal tents with either cloth or wire netting, as carried on extensively and effectively in this area, should be tried. Mosquito-proofing should be supervised and should meet the specifications noted in the Technical Appendix.

Although **mosquito bars** are the most generally available and the most practicable means of screened protection, their usefulness has often been limited due to carelessness. Mistakes made in the past are that bars have been stowed aboard ships so as not to be immediately available upon landing. In certain instances the loss of such protection for even one or two nights has been followed by epidemics of malaria. Provisions should be made to secure not only sufficient mosquito nets so that each man may have one, but for an addi-

tional supply for replacement purposes. An inspection routine should be established which will insure that each man is sleeping under a net, and that the net is properly used. (See Technical Appendix.)

3. Spray killing of mosquitoes. The killing of adult mosquitoes with pyrethrum sprays is a markedly effective measure of malaria prevention. The equipment and methods available for this purpose are described in the Technical Appendix. It will be noted that a new preparation, Freon-pyrethrum aerosol, in pressure cylinders is being made available. More recent experimental evidence indicates that insecticides are valuable not only in screened quarters, but are of potent effect in outdoor areas as well. A system of routine spraying should be required, and both indoor and circumscribed outdoor areas, wherever mosquitoes are prevalent, should be included. There is some evidence to indicate that sprays in addition to killing mosquitoes have a certain repellent effect which may persist for some time.

4. Repellents. Mosquito repellents are destined to play a far greater role in the prevention of mosquito bites and therefore in preventing malaria, than ever before. As will be seen by reference to "Use of Chemical Repellents" (Technical Appendix), new preparations are being made available which greatly exceed the effectiveness of those previously in use.

The prime importance of these preparations is that they may be used under military conditions in which no other protection from mosquito bites is feasible. Night sentries, jungle patrols, and other similarly exposed men should be required to use one of these repellents. Where malaria rates are high, their use in camps will often be indicated.

Despite the experimental indications of nontoxicity, individuals using repellent lotions should be alert to the possibility of skin irritation, particularly where usage is fairly constant.

5. Protective clothing. The use of headnets, gloves, and leggings should be required whenever feasible. It is of greater practical importance, however, that men should not be allowed to remain half-dressed during the twilight, night, and dawn hours, as negligence of this type has caused much malaria in the past. During the active biting hours shirts should be worn with sleeves rolled down, and wearing of trousers rather than shorts required. A useful procedure is that of encasing the lower borders of trouser legs by drawing the socks up over the outside.

6. Outdoor exposures. It is important that men in attending motion pictures and other night outdoor gatherings are not unduly exposed. The screening of moving picture theaters may occasionally be feasible, but it is more practical to arrange that such gatherings be held only at well controlled

locations found to be free of mosquitoes. Improperly dressed men should be excluded from outdoor gatherings.

Highly malarious areas should be out of bounds for troops, especially at night, except where miltary necessity requires their being there. Swimming should be prohibited after dusk and in the early morning; similarly, shower baths should be taken during day time and not during mosquito biting hours.

Often in noncombatant bases it is essential for troops to engage in practice maneuvers some of which are held at night. Authorities directing such maneuvers should make every effort to see that they are held in the least malarious parts of the island, and that a rigid enforcement of all applicable measures, such as have been described, be enforced to protect individuals against mosquito bites.

Night work in outdoor places should be reduced to an absolute minimum.

B. Elimination of anopheline breeding places. The elimination of mosquitoes is a joint responsibility of each individual bivouac group or camp and of the Malaria Control Unit. (See reference C.) It is the duty of the latter to survey camp sites, determine breeding areas, draw up programs of anopheline elimination, and to instruct and supervise men provided by the organizations concerned in the carrying out of these projects. Malaria Control Units are required to inspect routinely each area to check the effectiveness of antimosquito measures. Units will provide necessary material to all organizations.

The prime objective of this program is anopheline control which requires control measures of a specialized type. Pest mosquito control is not a responsibility of Malaria Control Units, nor should men assigned to anopheline control be diverted to the elimination of pest mosquitoes until the anopheline situation is well in hand.

In intermediate areas affecting various camps, but not the responsibility of any individual organization, control measures will be undertaken by personnel of Malaria Control Units. Under certain conditions, requests will be made of organizations most vitally concerned for their assistance in such areas.

1. Methods of mosquito control in camps. Much useful and practical information on the elimination of mosquito breeding will be found in the Technical Appendix. Emphasis in control measures should be placed upon development of permanent and semipermanent projects to eradicate breeding places; otherwise a continuous oiling program is necessary.

2. Man-made malaria. A great number of man-created breeding places for mosquitoes have followed incidental to engineering and construction projects. Much of this may be prevented. Considerable dependence will be upon engineering and construction organizations not only to prevent, but to aid in

elimination of natural breeding places with the equipment already present in the area in which work is being carried on.

It is essential that prior to beginning engineering projects requiring impounding of water, or otherwise creating new malaria breeding hazards, the Malaria Control Units be consulted in order to effect a satisfactory solution of the problem.

C. The control of carriers of malaria. Two human carrier sources of malaria exist on malarious bases; that in natives and that in seeded troops.

1. **Natives.** The most important sources are the chronic carriers among the natives which have long been occupants of the various island bases. Natives imported from other malarious islands for labor purposes create an additional hazard.

Surveys conducted by Malaria Control Units throughout the area to evaluate the danger of natives from a malaria standpoint, have shown both resident and imported natives to be highly malarious. Single blood film examinations have often revealed as high as 50 percent of a group to be positive for malaria parasites. In addition, tuberculosis, bacillary and amoebic dysentery, filariasis, and other diseases of hazard to military forces are prevalent among such groups.

(a) Imported native labor. One of the most serious outbreaks of malaria in this area has been traced to the introduction of a native labor force in a troop area prior to the inauguration of an effective program of control to protect the troops. Until satisfactory control is established, native labor, either local or imported, cannot be employed except at the cost of losing many man-days of sickness in military forces.

(b) Specific measures to reduce the hazard of native carriers of malaria.

Mass therapy of highly malarious groups should be attempted by Malaria Control Units in order to reduce infectiousness of natives. It must be borne in mind, however, that there is considerable question as to the effectiveness of such measures. Programs for mass therapy on natives should be repeated at frequent intervals throughout the malarious season. The frequency with which these procedures should be carried out may best be determined by thick film blood surveys taken at various intervals.

Segregation of natives. No natives should be permitted to reside within one and one-half miles of bivouac areas. Occasionally it may be possible to move small groups of natives, with the permission of local authorites, to areas away from troops; usually it is more feasible to move the camps, or best to prohibit selection of campsites in areas adjacent to native settlements.

Restriction of movements of natives. Military settlements should be off limits to natives other than those

whose employment in camps is essential. Native working parties when engaged in labor in troop areas should carry on their activities during day-light hours, and be removed in time to avoid their being bitten by anophelines at work sites in the early morning and early evening hours.

Military personnel should not be permitted in native villages.

Antimalarial measures in native villages. Where troops must be in close proximity to native villages, not only should mass therapy of natives be contemplated, but Malaria Control Units and camps situated nearby, should by joint effort, carry on a careful anopheline elimination program centering around the villages. Spray killing of adult mosquitoes in native villages should routinely be carried out, preferably with freon-pyrethrum mixtures.

2. Control of carriers in troops.—Actual experience, as indicated by surveys of military units who have suffered high malaria rates, does not indicate that even well seeded troops are important sources of malaria. Prompt diagnosis and thorough treatment is probably responsible. The early recognition of relapsing cases of malaria is important as during secondary attacks the patient is most apt to be infectious to mosquitoes. Routine follow-up of patients after treatment will many times detect carriers who can then be promptly rendered noninfectious by proper treatment.

D. Reduction of clinical cases by suppressive treatment. Suppressive treatment should never be started prior to arrival at bases where combatant conditions do not exist. It is much more important that measures which actually prevent rather than those which suppress be attempted first. However, if malaria should appear in such numbers as to threaten seriously the efficiency of operations being undertaken, suppressive drugs may be started and continued until such times as the measures of protection may be afforded the troops.

In bases previously occupied, Malaria Control Units will already have been established and should be consulted upon arrival to determine the need for suppressive treatment at that base.

X. PREVENTIVE MEASURES IN TROOPS OCCUPYING MALARIOUS ISLANDS UNDER COMBAT CONDITIONS.

In no other organizations is it more essential that a well formulated antimalarial program be prepared and followed than in units about to enter malarious bases under active combat conditions. Contrary to what might be expected there are many important measures which may be taken.

A. Organization and plan for combating malaria. When information is first received of prospective operations on a malarious base, each major organization should appoint an officer to be known as "malaria control officer." His general duties should be to make an estimate of the malaria situation and to formulate a program of antimalarial measures which will be applicable to the specific military operations contemplated.

(a) Season. The malaria rates to be expected will vary markedly according to the time of year in which operations are to be carried on, especially in the southern-most malarious islands, where the peak of the malaria season occurs during the period November to May. Operations carried on in other months will be much less effected by malaria.

In the Solomon group and northward, the malaria season begins a month or two earlier and lasts a month or two longer.

(b) Hazard due to prior occupation by natives and by enemy forces. If natives have been present on a base in any considerable numbers, the malariousness of the base to be occupied may be considered to be greatly enhanced. A further hazard may be that due to the presence of Japanese military forces. Malaria surveys have shown as high as 70 percent of Japanese prisoners to be positive for parasites, and over two-thirds of the positives to show gametocytes. Although it is doubtful that if any such high proportion of malariousness would be found in average groups, the findings suggest the real hazard to troops required to engage the enemy at close quarters.

2. Program for training. All officers and enlisted men should be made familiar with the general nature of malaria, its military importance, and with their respective duties and responsibilities in preventing the disease. The general scope of the training program should be as follows:

(a) Medical Officers. Where the medical officers have had little clinical experience with malaria, arrangements should be made to hold rounds in the wards of any hospital where malaria cases are being treated. Conferences should be held in order that there may be an agreement on the plan of treatment and disposition. A simple plan should be devised for the prompt reporting of malaria cases to the malaria control officer. He will require such information to detect unduly high malaria rates and institute proper corrective measures. If laboratory facilities are planned, enlisted technicians should be trained by Malaria Control Units for the laboratory diagnosis of malaria.

(b) Line Officers should be instructed in the mechanism of transmission of malaria, the nature of the disease, its treatment, and the effect upon troops. Malaria Training Manual No. 2, for all officers, may be obtained from Base Control Units and used as a guide for instruction.

The limitations of suppressive treatment should be explained to them as well as its value. Especially should the need of a rigid plan of individual supervision of suppressive treatment be emphasized, and a specific plan for such supervision be drawn up. The effect of fatigue and malnutrition as a factor which tends to largely nullify the value of suppressive treatment should be emphasized.

There should be a clear understanding of what is meant by malaria discipline, the function of which is almost exclusively that of command. The value of contemplated preventive measures and the responsibility of officers to enforce such measures must be made clearly evident.

(c) Enlisted men should be given an intelligent concept of the nature of malaria, its transmission, and its importance both to themselves and to the success of the organization. Malaria Training Manual No. 3 may be used for this purpose. Most important, the men should be made thoroughly familiar with the measures which they as individuals must take for their own protection. It should be stressed that there will be full intent to see that all men fully comply with the measures of prevention. They shoud be specifically instructed in the importance of the proper use of a bed net, the value and limitations of suppressive treatment, and in the wearing of proper clothing.

3. Procurement of drugs and other malaria control supplies. Methods of obtaining, and estimates of quantities required for malaria control needs are outlined in appendices III and IV of Training Manual No. 2.

4. Bed nets. The malaria control officer should make plans to insure that every man will have the use of a bed net immediately upon landing, or at the earliest possible time that the military situation will permit their use. Replacements should be made available.

5. Repellents. He should procure insect repellents, instruct men as to their proper usage and arrange to make them available to all troops. Great emphasis should be placed on the value of such preparations and careful plans drawn up to insure their systematic usage. In this connection the feasibility of spraying with repellent both the skin surfaces and the clothes of men should be considered.

6. Insecticide. He should procure freon-pyrethrum cylinders and instruct the men in their use. It seems not unlikely that these cylinders will be of great value in spraying men sleeping in fox holes, and in spraying dugouts and other semi-open places on the front lines. (See Technical Appendix.)

7. Antilarval measures. He should organize his mosquito control squads so that the oiling of breeding places may begin functioning at the first opportunity permitted by the military situation. Chemical warfare decontamination hand sprayers are well suited for this purpose and if a gas attack impends, can be rapidly reconverted to their original use. Spare

parts for these sprayers, especially rubber gaskets should be obtained. No. 2 navy diesel fuel oil is usually readily obtainable and arrangements for constant supply should be made. Oiling crews should be prepared to function behind front lines especially in rear echelons which are under less active combat conditions. The possibility of oiling operations in semi-permanent front line conditions and when enemy action is not great should be contemplated. Wherever oiling operations are found to be feasible they can be expected to reduce tremendously the malaria experience of the organization.

B. Malaria control program during phase of occupation.

1. The malaria control officer's duties during actual landing operations make him responsible that a rigid application of all possible measures is being undertaken. It is his duty to supervise oiling operations. He should be required to inspect troops in their separate locations, observe the malaria discipline, and make recommendations to proper authority when conditions are not satisfactory. In making his recommendations he should be particularly guided by the malaria rates reported by individual units.

2. **Suppressive treatment.** Paragraph E of section VI, discusses the dosage indicated under combat conditions. The malaria control officer should set up the most rigid system possible to see that each man actually gets and takes his drug. Roster lists, when possible, should be used, and it is highly important that a responsible officer or noncommissioned officer actually witness each individual swallow the drug. In small groups acting independently the senior noncommissioned officer should undertake this responsibility.

The first administration of suppressive treatment should be begun **prior** to the landing operations. This is done in order to overcome some practical difficulties. First, to start atabrine suppressive treatment during the heat of battle is doomed to failure, for unless a system of administration is already a matter of routine, it cannot be initiated under battle conditions. Secondly, many individuals show intolerance when atabrine is first administered and if the system is set up prior to landing such individuals may become adjusted to the drug and if not they can be placed on quinine 10 grains daily. Thirdly, experience in this area has repeatedly illustrated that the initial administration of atabrine to troops, concurrently with the prevalence of enteritis and diarrhea, which is so frequent in the early phases of landing operations, seems to greatly enhance atabrine intolerance.

3. **Laboratory** facilities for accurate thick film diagnosis for malaria should be established at the earliest possible date. The lack of such facilities has in the past led to confusion of malaria with such entities as respiratory infections, bacillary dysentery, infectious hepatitis, dengue, and other febrile diseases which may simulate malaria.

4. Establishment of Malaria Control Unit. The above plan places the responsibility for the control of malaria in the early phases of combatant operations upon the organizations taking part in such operations. As soon as combatant conditions subside to the point where entomologists, engineers, and other technical personnel can function effectively, one or more Malaria Control Units will be established. The scope of antimalarial measures will then gradually expand so as to include such a program as described in the section on Preventive Measures Applicable to Noncombatant Bases.

XI. PREVENTIVE MEASURES APPLICABLE TO FORCES AFLOAT.

Relatively few cases of malaria have appeared among the crews of either naval or merchant ships operating in the South Pacific Area. The program for the prevention of the disease in such units is fairly simple.

A. General measures. Using Malaria Training Manuals Nos. 1, 2 and 3 as guides, lectures should be given aboard ship to familiarize all members of the crew regarding the nature of malaria, mechanism of its transmission, and the measures by which the disease may be prevented.

Medical Officers may extend their clinical knowledge of the disease by making rounds on the malaria wards of hospitals whenever ships make shore contact. At such times their laboratory technicians serving aboard ships should be trained by Malaria Control Unit laboratories in the thick film technique for diagnosing malaria.

B. Specific measures.

1. Anchorage. Where stops are made at malarious islands, ships should be anchored off shore as far as possible in order to minimize the danger of mosquitoes flying aboard. Usually one-half mile suffices, but the direction of the prevailing wind may reduce or increase the hazard.

2. Liberty. Although cases of malaria may result from sending working parties ashore, or by allowing liberty on malarious islands, the malaria hazard will be almost nil if contact ashore is restricted to daylight hours. Overnight liberty is apt to be exceedingly dangerous although this again depends upon the malariousness of the individual location and is a matter which may be determined by consultation with Malaria Control Units.

3. Suppressive treatment. Suppressive treatment should not be given to personnel remaining ashore for temporary periods.

4. Landing forces. Where landing force operations are contemplated, suppressive treatment may be required. In addition, other procedures, as outlined in the section Preventive Measures In Troops Occupying Malarious Islands Under Com-

batant Conditions, will be applicable and should be employed.

5. Survivors. It should be mentioned that in the past survivors of lost ships have been landed on malarious bases almost totally unprotected. In such cases serious epidemics of malaria, some of which may have been prevented, have followed brief periods of exposure. Where possible, ships with survivors should be diverted to nonmalarious bases, or, at malarious bases, Malaria Control Units should be contacted immediately so that some sort of protection may be afforded.

6. Prevention of dissemination of anopheline mosquitoes to nonmalarious islands and bases. Attention is called to a directive (reference D), which specifies measures to prevent ships from conveying malaria mosquitoes from malarious to nonmalarious bases. Freon-pyrethrum insecticide cylinders provide by far the most effective method of carrying out the killing of adult mosquitoes aboard ships, and should be used in preference to hand sprayers.

XII. PREVENTIVE MEASURES APPLICABLE TO INDIVIDUALS AND TROOPS PASSING THROUGH OR ON TRANSIENT DUTY AT MALARIOUS BASES.

A. Individuals. Not infrequently individuals must either pass through or perform duties for short periods on malarious islands. In the forward areas where malaria is apt to be most prevalent, the danger of contracting the disease may be considerable if no precautions are taken. The following rules can be laid down:

1. Take along a mosquito bed net if there is any question as to whether one can be obtained at destination.

2. After arrival. Avoid exposure to mosquito bites from dusk to dawn by getting under mosquito bed nets early in the evening and arising late in the morning. Before retiring search the inside of the net with a flashlight to kill any mosquitoes which may have obtained entrance. See that the net is arranged so that there is a minimum opportunity for arms and legs to come in contact with the net and allow mosquitoes to bite through. (Note: Persons sleeping in nets on arising usually note a large number of bites on the knees and elbows. An insect repellent should be taken along. Before retiring smear the solution on these particularly vulnerable parts.)

3. If it becomes necessary to be out at night, or dusk, or in the early morning, apply insect repellent to exposed surfaces at hourly intervals.

4. Try to sleep in screened quarters, if possible. If malaria is especially prevalent use a bed net as an additional precaution.

5. Suppressive treatment. The taking of quinine or atabrine to delay the onset of symptoms of malaria is not in-

dicated during transient stays at malarious bases. Even on the more malarious bases, the individual's chance of getting malaria in such short periods as 10 days, if proper precautions are taken, are exceedingly small.

B. Troop movements. Occasionally, plans may call for troops to stop off for brief periods at malarious bases preparatory to further movements to other localities. In such instances, the following considerations are pertinent:

1. Stop-overs on the more malarious bases should be avoided if at all possible. Otherwise, in the confusion of landing and setting up temporary camps, the exposure to mosquitoes is apt to be great with the result that many cases of malaria will follow. Where essential, it is preferable that brief stop-overs be made at bases where malaria is least prevalent. In such a case, it is advisable to send an officer to the stop-over base in time to make preparation for the reception of troops. This officer should contact the Malaria Control Unit at the base concerned in order to select a camp site least likely to result in malaria infections.

2. The movement should be so planned that the troops may land in the morning with sufficient time to set up camp and permit most of the men to be under their mosquito nets by nighttime. The men should have been previously instructed in the proper use of mosquito nets, insect repellents, wearing of mosquito proof clothing, and all other measures described in the section pertaining to preventive measures for forces occupying malarious bases.

3. The advice of the local Malaria Control Unit should be followed regarding the necessity of taking suppressive treatment.

XIII. PREVENTIVE MEASURES APPLICABLE TO AVIATION FORCES.

Although malaria in any member of a fighting force is a serious deterrent to fighting efficiency, its occurrence in flight personnel is apt to be particularly costly. In general, the principles and recommendations laid down in other sections apply even more importantly to aviators and ground crews, and these sections should be consulted by medical and line officers concerned with a view of inaugurating every feasible preventive measure. Certain problems, however, concerning the control of malaria in flight personnel require special consideration.

A. Screened housing. Aviators in their constant movement from base to base, frequently do not have the protection afforded in well established camps, and consequently, their exposure to malaria and other disease is increased. For this reason it is deemed highly important that insect proof housing should be provided for transient aviation crews. High prior-

ity should be given in the assignment of housing requested for such purpose.

B. Selection of airport sites. When the selection of airports on malarious bases is pending, the malaria hazards presented should be taken in account. By directive (Reference A, par. 6), it is required that Malaria Control Units be consulted in this regard and that their recommendations be given full consideration.

C. Individual measures. To a large degree the measures which will afford best protection to aviators depend upon the discipline of the individual. The use of mosquito bars when sleeping, and of mosquito repellent when exposed during biting hours, will alone greatly reduce malaria morbidity.

1. Mosquito bars. It should be required that bars be carried in planes in sufficient number to be available to each member of the crew and responsibility assigned to insure that they are routinely and properly used.

2. Repellents. The systematic application of insect repellents during the mosquito biting hours should be prescribed and made a matter of routine. The distribution of repellents should be such that they will be available at all times.

3. Suppressive treatment. Drug suppression presents several problems peculiar to aviation forces.

(a) Drug tolerance in flight personnel. Quinine, even in small daily doses of 5 to 10 grains, appears to be contraindicated. The frequency of untoward symptoms, particularly ringing in the ears, deafness, and vertigo, render the drug potientially dangerous to pilots. Atabrine, on the other hand, after the phase of initial intolerance has been overcome appears to be safe. No noticeable ill effects have been reported by pilots even after prolonged use, and flight surgeons observing aviators flying under active conditions of combat and at altitudes of around 30,000 feet, have reported no noticeable ill effects from the drug.

It is important that pilots and members of their crews be grounded during the initial administration of atabrine in order that flight surgeons may observe for individual intolerance such as nausea, vomiting and diarrhea. These symptoms are apt to come on several hours after the first dose is administered, but will be rare if the drug is employed in the dosage recommended below.

(b) When indicated. When flight operations are largely confined to malarious bases and when crews remain only for short periods on nonmalarious bases, suppressive treatment is indicated and should be continuously employed. Where flight personnel are stationed for more or less prolonged periods at airports where malaria is well under control, suppressive treatment should not be used.

(c) Dosage. One-half atabrine tablet (0.05 gram) should be given daily after a meal, with a full tablet

(0.1 gram) on Sundays. The administration should be rigidly supervised and enforced by a plan which will give some promise of regularity in the taking of the drug. Where a single dose is missed, the next should be doubled.

Dosage during periods of fatigue and exhaustion. Flight surgeons may deem it advisable to increase the dose of atabrine to one full tablet daily (0.1 gram) where crews are subjected to fatiguing and exhausting flight operations.

(d) When to discontinue suppressive therapy. Inasmuch as suppressive treatment does not prevent infection, and that malaria will remain latent only during the period in which fatigue or exhaustion do not precipitate symptoms, flight surgeons should discontinue the drug whenever operating schedules permit.

(e) Routine thick films. Flight personnel on suppressive treatment should, if feasible, be thick filmed every 10 days to detect latent cases. Malaria Control Units at all bases will render this service upon request if other laboratory facilities are not available.

(f) Post treatment observation of malaria cases. The high relapse rate of the malaria strains found in this area require that flight personnel who have been ill be kept under most careful supervision after treatment. Routine thick films should be periodically taken as a post-treatment measure (if possible at weekly intervals for three or four months). Inasmuch as a potent factor in precipitating relapses is early return of men to fatiguing duties, pilots should be grounded at least 10 days and preferably more, following the cessation of treatment. Aviation personnel who have had attacks of cerebral malaria should be carefully observed during convalescence to detect minor neurological disturbances which might easily be missed.

4. Prevention of dissemination of mosquitoes by aircraft. Freon-pyrethrum insecticide pressure cylinders are available for the spraying of airplanes. This preparation is superior to hand sprays and has the advantage of being noninflammable. These cylinders should be made a part of the equipment of all planes which are apt to fly between the various bases.

Pilots are responsible for the spraying of their own planes (reference E and F), and strict enforcement of the procedure will be required.

XIV. PREVENTIVE MEASURES APPLICABLE TO NONMALARIOUS BASES.

It is essential that island surgeons, or other senior medical authority at nonmalarious bases, institute all possible measures to prevent the introduction of malaria:

A. Check upon the proper spraying of ships and planes. Routine inspection should be established to insure that directives requiring the spraying of ships and aircraft (reference D, E, and F) are properly carried out.

B. Mosquito control at airports. The elimination of mosquito breeding places at airports is a measure which will help prevent anopheline mosquitoes from becoming established on nonmalarious bases. Programs of draining, ditching, filling, and oiling should be very thorough in areas adjacent to landing strips. Continuous surveys for mosquito larvae and adults, either by entomologists, or individuals trained by them, should be carried on at each airport. Malaria Control Units may be called upon to assist in outlining the program of control.

C. Reports on cases of malaria presumed contracted on nonmalarious bases. All medical organizations should be instructed by island surgeons to report immediately if a case of malaria is encountered which appears to have been contracted on a nonmalarious base. The serious implications of reports of this nature are obvious, and thorough, responsible investigation should follow. Blood films confirming the diagnosis of malaria should be obtained and kept for future reference.

D. Reports on finding anophelines on nonmalarious bases. Similar instructions should be issued to require that when suspected anophelines are found, either larvae or adults that a report be rendered immediately, and specimens in question be preserved to permit a verification of the species diagnosis.

It is requested that Malaria Control Units be notified of reports of the nature referred to in paragraphs C, and D, above.

XV. TECHNICAL APPENDIX ON CERTAIN CONTROL MEASURES APPLICABLE UNDER MILITARY CONDITIONS.

(Extracted in part from War Department Circular letter No. 22, 16 January 1943.)

A. Protection by screening.

1. **Screening.** The following general principles should be observed if screening is to give its full value as an antimalarial measure.

(a) The screening must be so applied that breakage will be minimal, and that the doors and windows will not facilitate mosquito passage. For instance, screen doors should open outwards, and should be on the windward side of a building, if possible. They should be strongly constructed so they will not sag or warp. They require springs so that they will close automatically. The places where a foot or hand would naturally be applied to open a screen door should be protected

with a cross strip of wood or metal. Screen doors should shut against battens, which are strips of wood or metal, to block entry of mosquitoes through the space between door frame and door.

In highly malarious areas it is desirable to have double screen door barriers with a vestibule between.

(b) **Careful attention must be paid to the closing of all possible apertures not screened,** such as cracks and knot holes, spaces where floor or wallboards have separated, openings between flooring and walls, corner openings where joists come together, holes where window shutter propsticks extend into a room for easy handling, ventilating pipes and shafts, etc. Holes may be covered with tin shingles or pieces cut from ordinary tin cans. A filler for holes and cracks may be made by boiling shredded paper and flour into a fairly homogeneous mass and then adding sand and cement to form a plastic which may be moulded into the holes. This filler is somewhat pliable and will retain its place fairly well. Toilet paper is a suitable tissue for use in making this filler.

(c) **Proper routine maintenance of screening is essential,** with prompt and effective repair of rents and tears, and discovery and blocking of new cracks and knot holes. In malarious areas, the great importance of these apertures for mosquitoes is out of proportion to their seeming insignificance. The soldiers who occupy hutments and barracks should be taught to make all minor repairs. Strict supervision of screening is essential. Under some conditions it may be desirable to assign an enlisted man as mosquito-proofing maintenance orderly whose duties it would be to inspect all screening at regular intervals, making such repairs as are within his capabilities and reporting others to proper authorities.

(d) **Types of screening material.** Steel wire screen cloth which has been galvanized is suitable and the most economical for semipermanent buildings. Standard 18 mesh-wire should be specified.

For less permanent dwellings fine cloth netting is very valuable. The material should be a 20 mesh, stiff bobbinet, preferably dyed khaki.

2. **Use of sleeping nets.** Nets to protect sleeping individuals are useful in preventing malaria but they must be properly employed and properly maintained. They must be so adjusted and used that mosquitoes cannot feed through the mesh because the net touches the individual. The lower edge must be so tucked in that no opening is available for mosquitoes to enter. Overhead frames should be provided for bed and cot nets. These should not have sharp points which will catch and tear the netting. Nets used in small tents should be suspended from and conform to the shape of the interior of the tent. Shelter tents nets should not be used over the outside of the tents but hung inside. The nets should be folded up by day. When the net is entered at night the interior should be inspected for stray

mosquitoes. Rents in nets may be repaired with adhesive tape, sewing or patching.

B. Protection by spray-killing adult mosquitoes.

1. Pyrethrum insecticides. Pyrethrum flowers contain active principles which are grouped under the term pyrethrins and kill all species of mosquitoes and certain other insects by destructive action on the central nervous system. The sprays are nontoxic to man and animals (although liberal application of a kerosene-pyrethrum spray to the skin may cause local irritational inflammation). Pyrethrins rapidly disintegrate by a photochemical catalytic reaction when exposed to sunlight and oxygen. Pyrethrum concentrate and sprays should be kept in tightly stoppered, light-proof containers. Containers should never be left open in the sun. In sealed containers pyrethrum extracts will maintain their potency for a year or more, even in the tropics. If a pyrethrum spray fails within three minutes to kill all the adult mosquitoes with which it comes into contact, it no longer contains the standard amount of pyrethrins and is not suitable for use.

Three types of pyrethrum products are supplied. There is first a 20–1 concentrate, each gallon containing the oleoresins of approximately 20 pounds of flowers, with not less than 75 to 100 grams of total pyrethrins per gallon, or 2 to 2½ grams per 100 cc. This 20–1 concentrate is diluted with 14 parts of a good quality of water-white, preferably odorless, kerosene and may be sprayed from various types of mechanical sprayers, such as are described below.

Secondly, in areas where there may be difficulty in obtaining kerosene for diluting the concentrate, a prepared ready-to-use pyrethrum spray is supplied. This conforms to class AA rating, as defined in the Department of Commerce Standard Specifications. This rating is based on actual performance killing tests and these AA sprays will contain 150 to 180 milligrams of pyrethrins or their equivalent per 100 cc. With either of the above two sprays, about one-half ounce is required to spray effectively 1,000 cubic feet.

Finally, pyrethrum is supplied in containers holding a mixture of 20–1 concentrate, oil of sesame, and liquid freon, as described below.

(a) Freon-pyrethrum aerosal. Pyrethrum may be dispersed from pressure cans or cylinders containing a maximum of 1 percent pyrethrins, 2 percent oil of sesame, and 97 percent freon. (Freon 12 is dichloro-difluromethane.) The oil of sesame is a synergist or activator, and enhances the killing power of the pyrethrins. The vapor pressure of the freon produces the necessary spraying pressure, which does not decrease as long as a drop of liquid is present in the closed container. As the freon containing the insecticide is sprayed it forms a fine mist from which the solvent evaporates almost immediately, leaving the pyrethrum and sesame suspended in the air as a

cloud of fine droplets called an aerosol. The freon is non-toxic to man and mosquito and it is noninflammable. It is used simply as an expellent to disperse the pyrethrum and oil of sesame.

The pressure in freon cylinders varies with temperature. For example, it is 37 lbs. per sq. in. at 40 degrees F., 84 lbs. at 80 degrees F., 116 lbs. at 100 degrees F., and 205 lbs. at 140 degrees F. Various types of freon-pyrethrum pressure cans and cylinders are available. One pound of freon-pyrethrum mixture is sufficient to spray about 150,000 cubic feet of space when properly used. It is liberated in 12 to 14 minutes of continuous use. To spray a room, hutment, or native dwelling, the can is carried rapidly toward all corners of roof, ceiling, or floor while the spray is allowed to escape. No direct hits on mosquitoes should be attempted, as this wastes spray. About 4 seconds of spraying per 1,000 cubic feet is usually sufficient in military huts. Somewhat longer spraying for the same cubage is generally required for native huts. It is best to spray under the eaves of a hut before going inside. The freon-pyrethrum spray is so effective that it can be used sparingly and without waste.

(b) Hand atomizers or spray guns. Small household-type guns are useful for casual spraying of quarters. They consume relatively greater amounts of insecticide than other types of sprayers, but may be used to advantage by the troops themselves for occasional spraying.

Paint gun sprayer assemblies. Pyrethrum insecticides can be effectively sprayed through an ordinary paint gun if a source of air pressure of 15 pounds or more is supplied. The source of the pressure may be in tanks pumped by hand or by gasoline or electric motor-driven compressors. Solidified carbon dioxide (dry ice) when available, in suitably constructed pressure tanks, is a good expedient.

C. Protection by the use of chemical repellents. Various essential oils and synthetic products have been used, as creams or lotions applied to the skin, to repel mosquitoes. Most mosquito repellents have had one or both of two major defects; (1) very transitory or weak effect, and (2) risk of toxic poisoning by absorption through the skin, especially when the repellent must be used liberally during extended periods of time. For example, diethylene-glycol is a mosquito repellent but is reported to be toxic when absorbed through the skin and apt to damage kidney and liver tissue if used freely for considerable time.

Three good repellents, 612, indalone, and dimethylphthalate are being made available to military forces. Of these, 612, will give protection against mosquitoes for about four hours after liberal application even under sweating conditions. Indalone will do about as well, except under sweating conditions when it should be renewed half-hourly. Dimethylphthalate is slightly less effective than 612, but more effective than

indalone. All are better than any repellent available heretofore.

D. Antilarval measures within and adjacent to camps.

1. Semipermanent measures.

(a) Clearing. The cutting of grass and clearing of brush within and near camps apparently is of value by decreasing available daytime hiding places for adult mosquitoes.

(b) Draining and filling. Puddles and small pools constitute the chief breeding areas of **A. punctulatus** during the wet season. A good system of drainage will reduce the number of such places which otherwise would require continuous oiling. A few shovelfuls of dirt will eradicate many prolific breeding pools.

2. Larvicidal oiling.

(a) Discussion. Suitable oils, properly applied, will kill all species of mosquitoes in the aquatice stages and will also destroy sheltering vegetation at the edges of breeding places. The chief killing factor is a toxic action following contact with the tracheal cells of larvae and pupae. Consequently, the best larvicidal oils are those which penetrate most quickly, and with the greatest toxic effect, into the spiracles and thence into the trachea of larvae and pupae. What is required is a cheap, toxic oil or mixture of oil of suitably toxicity and viscosity which, when sprayed on the surface of the water, will spread well and form a uniform, persistent and table film. The best larvicidal oils will kill in less than 30 minutes under these conditions. Number 2 diesel fuel oil, a more or less standard item on the supply lists of troop units, adequately meets all these requirements.

The ideal specifications for a larvicidal oil are the following:

Specific gravity 20/4—0.83–0.86.
Viscosity (Saybolt Universal at 100 degrees F.)—31–43.
Initial boiling point—297 degrees—414 degrees F. (165 degrees—230 degrees C.).
Final boiling point—Maximum—800 degrees F. (426.7 degrees C.).
Spreading coefficient—Minimum—17.0.

Kerosene or gasoline may be used as larvicides and will give a good kill, but they form transitory films, are expensive, and may constitute a fire hazard. Occasionally it may be desired to kill all larvae in a well by a film of gasoline, which soon evaporates, leaving no taste in the water. Lead gasoline should not be used in wells from which the water is used for drinking.

Because of their relative nonvolatility, waste motor oils and crude oils are not highly toxic to larvae. However, heavy applications of these oils will so contaminate small

collections of water (this method can be safely used only on pools that are not subject to excessive movements or overflow) that breeding is prevented for extended periods of time. In the absence of proper larvicidal oils for routine spraying operations, these oils may be also utilized by mixing them with kerosene, generally in the proportion of 1 to 3, respectively, adding if possible about 2 percent of castor oil. However, the amount of kerosene to be added will have to be determined by experiment.

(b) Application of oil. General. Oil may be effectively applied to small collections of water by means of an oil-soaked broom, an oil mop, or oil-soaked waste tied to a stick. An ordinary waterpot may be used to pour oil on small collections of water.

(c) Sprayers. The knapsack sprayer consists of oil container, hand pump, and spray nozzle, and is carried and operated by one man. The ordinary sprayer has a capacity of 4 to 5 gallons and a spraying range of about 25 feet. The knapsack sprayer is a practical and economical apparatus for applying oil to ditches, small ponds, or other collections of water which can be reached by the spray.

(d) Continuous oilers. Where long stretches of small streams or ditches are breeding mosquito larvae, it may be feasible to use some method of continuous application of oil.

Drip oilers have proved very efficacious in this area. A tin or drum of about 5 gallons capacity is placed on supports over a stream or ditch so that oil will drip on the water surface. The size of the hole will govern the amount of oil dropping from the container. In homemade containers a nail hole may be used, with a nail left loosely in the hole. It may be necessary to use some string to form a washer around the nail head. The can should be several feet higher than the stream surface so that oil will spread quickly when drops strike the water. The rate of flow required to furnish a satisfactory film depends on circumstances. Generally, an average flow of from 10 to 20 drops per minute will suffice for each foot of width of water in the stream.

Submerged oilers are containers having two small openings. They are designed so that when sunk to the bottom of a stream or pond, their oil will escape through one opening and be replaced by water which enters through the other. These cans have the disadvantage that they are difficult to adjust so that oil will flow properly, as the openings are easily clogged.

Oil may be applied continuously by means of a weighted submerged bag of oil-soaked sawdust. Or oil-soaked sawdust may be scattered over the surface of a breeding place.

(e) Amounts of oil required. Using Diesel oil No. 2, about 9 gallons are required per acre of water surface for

complete coverage with a uniform, stable oil film. With any ordinary knapsack sprayer of the Panama type, one laborer can oil about five acres of breeding area per day, if the terrain is not difficult. In usual practice the amount of oil necessary to produce a uniform film may vary from 10 to 20 gallons per acre. The amount of floatage and vegetation will make a considerable difference. It is usually necessary to spread oil once a week.

(f) Care of equipment. Equipment for spreading oil larvicides requires careful maintenance. It should be overhauled and thoroughly cleaned at reasonable intervals. Full sets of replacement parts should be stocked.

E. DDT (dichloro-diphenyl-trichloroethane).[1] **DDT** is a new insecticide which possesses two main advantages over previously used insecticides: (1) Prolonged residual effect against nearly all insects; (2) Effectiveness in extremely low concentrations. These characteristics give **DDT** a prominent place in the control of both larvae and adult mosquitoes.

1. Chemical and physical properties. DDT is a white powder, insoluble in water. Its solubility (by weight) in fuel oil and lubricating oil is 10 percent, crude kerosene 5–8 percent, xylene 56 percent, and cyclohexanone 100–120 percent. Solution in oil and kerosene takes place slowly, requiring 12 to 24 hours; the dissolving may be speeded by occasional stirring.

2. Mediums of use. DDT is supplied in three forms, as follows:

(a) Commercially pure DDT powder for the preparation of the oil and kerosene sprays. At the present time it is recommended that these sprays contain 5 percent **DDT** by weight.

(b) DDT emulsion concentrate containing 25 percent **DDT,** 68 percent xylene (solvent), and 7 percent triton X–100 (amulsifier). One gallon of this concentrate should be stirred into 4 gallons of water (salty, brackish, and alkaline waters are satisfactory), and the resulting emulsion is immediately ready for spraying. On standing, a creamy layer may form at the surface; this is of no significance, only requiring stirring of the emulsion before it is poured into the sprayer.

(c) 10 percent DDT powder (10 percent **DDT** in pyrax or talc) is supplied in 2-ounce cans for use as louse powder, and will be available in bulk for use in mosquito control.

3. Toxicity. Pure **DDT** and **DDT** dust are not absorbed from the skin, but when oily solutions are used absorption does occur, large doses leading to nervous irritability, tremors, convulsions, and possible liver damage. Therefore, men engaged in mixing or spraying the oily solutions of **DDT** must not allow the material to spill on or come in contact with

[1] Paragraph E prepared and added by the Division of Preventive Medicine, Bumed, Navy Department.

the skin. Occasional contact is not dangerous; repeated or prolonged contact is to be avoided. For this reason the decontamination type of sprayer is preferred; if the knapsack sprayer is used, it should be only half filled to avoid spilling. DDT is toxic when ingested, requiring the protection of food and food containers from contamination with DDT. The inhalation of moderate amounts of DDT is apparently not harmful.

4. DDT against mosquito larvae.

(a) Oil (lubricating, Diesel or crankcase), kerosene, or a mixture of the two, containing 5 percent DDT usually gives larval control for a week when applied at a rate of 1 to 2 quarts per acre. Under combat or other critical conditions, heavier application may be required. Proper dosage will vary, depending on vegetation, current, wind, rain, and other factors. Solution may be sprayed by knapsack, decontamination, power, or other sprayer, using a fine spray. The effectiveness is less pronounced if the solution is poured onto the surface. Drip-cans tend to "freeze" through precipitation of DDT at the valve or hole in the can.

(b) Emulsion (5 percent DDT), as prepared from the emulsion concentrate (25 percent DDT), is used in a similar manner to the oil solutions of DDT. Its advantage is that, like oil, it remains on the surface, but is not as easily blown aside by wind as is oil. Ordinarily the emulsion should be conserved for use against adult mosquitoes and flies.

(c) Dust. 10 percent DDT in talc is difficult to spread evenly at a rate of one pound per acre. For that reason, it should be thoroughly mixed with 3 or 4 parts of fine road dust, condemned flour, or other diluent, and distributed at a rate of 0.1 to 0.5 pounds of DDT per acre. (**Note:** Due to the large particle size of **commercially pure DDT**, it cannot be effectively mixed with diluent dusts in the field).

5. DDT against adult mosquitoes. DDT does not repel mosquitoes, but after obtaining a lethal dosage either from the air or from residual particles of DDT on surfaces, they become restless and attempt to escape, dying elsewhere. For this reason, **dead insects may not be found in treated areas.** In experiments, all mosquitoes trapped in the act of escaping from treated areas died within 2 to 12 hours.

(a) Residual spray. Solutions sprayed against adult mosquitoes possess residual toxicity after the DDT has settled to the exposed surfaces. The maximum residual effectiveness is obtained by applying sprays to the walls, rafters, screening, tent, vegetation, and other surfaces so as to obtain 0.1 to 0.2 grams of DDT per square foot of surface (2 to 4 cc. respectively of 5 percent spray per square foot). The DDT adhering to such surfaces will continue to kill mosquitoes (and flies) which alight on the treated areas for many weeks (or months, depending on weathering, washing, etc.). The DDT emulsion is best suited for this use, but oil or kerosene solutions

are almost equally effective. Too fine a spray is wasteful; a semifine, moistening spray is recommended, with the nozzle held 4 to 10 inches from the surface being treated.

(b) Spraying for direct action on adults in barracks, tents, dugouts, open areas, etc., requires a very fine, fog-like spray. One quart of 5 percent **DDT** in oil, kerosene or emulsion has been found effective over an area of one acre. In the open a considerable surrounding area must be treated to prevent the influx of mosquitoes into the controlled zone. The 10 percent dust is effective against adult mosquitoes when dispersed in a finely divided state, but is extremely susceptible to the variables of wind, temperature and vegetation. These materials, when used against adults, possess larviciding effects when they settle to the puddles and other breeding points in the area.

6. Experimentation now being done will probably produce additional methods of dispersing **DDT.** The most promising of these methods are as follows:

(a) Aeroplanes have been shown to effectively distribute **DDT** in oil solutions, emulsions and dusts. Special equipment is now being developed for use in this method of application.

(b) Smokes containing DDT are effective against insects; several chemical and physical problems must be solved before this method can be adopted.

(c) Aerosol bombs containing DDT are very effective. They will be procured as soon as certain mechanical difficulties have been overcome.

XVI. REFERENCE LIST OF DIRECTIVES PERTAINING TO MALARIA CONTROL IN SOUTH PACIFIC AREA.

(A) All Forces,	COMSOPAC, Ser. No. 0094b. Subject: Malaria Control Units, South Pacific Area, dated 13 November 1942.
(A) Army,	Headquarters USAFISPA, Subject: Malaria Control, South Pacific Area, dated 29 November 1942. Modification; 24 May 1943.
(B) All Forces,	COMSOPAC, Air-Mailgram, dated 10 February 1942. Conservation of Quinine.
(B) Army,	Headquarters, USAFISPA, Memorandum, dated 14 February 1943.
(C) All Forces,	COMSOPAC, Ser. No. 00169E, Subject: Mosquito Control Measures in the Prevention of Malaria in the South Pacific Area, dated 29 December 1942.

(D) All Forces, COMSOPAC, Ser. No. 0176, Subject: Prevention of Dissemination of Anopheline Mosquitoes to Nonmalarious Islands and Bases, dated 17 January 1943.

(E) All Forces, COMSOPAC, Ser. No. 0178, Subject: Prevention of dissemination of malarial mosquitoes by aircraft, dated 2 September 1942.

(F) All Forces, COMSOPAC, Ser. No. 0174, Subject: Prevention of dissemination of malarial mosquitoes by aircraft—responsibility for, dated 7 February 1943.

(G) All Forces, COMSOPAC Ser. No. 01619, Subject: Antimalarial organization and training program within military units, dated 13 September 1943.